



DRAFT

AQUATIC LIFE

AMBIENT WATER QUALITY CRITERIA

CADMIUM - 2015

EXECUTIVE SUMMARY

EPA has updated the Agency's recommended cadmium aquatic life ambient water quality criteria in accord with provisions of §304(a) of the Clean Water Act to periodically revise Ambient Water Quality Criteria (AWQC) in order to reflect the latest scientific knowledge. Recommended 304(a) water quality criteria for cadmium were originally developed in 1980 (EPA 440/5-80-025, U.S. EPA 1980), and subsequently updated in 1985 (EPA 440/5-84-032), 1996 (EPA-820-B-96-001) and 2001 (EPA-822-R-01-001, U.S. EPA 2001). Cadmium aquatic life criteria are updated in this revision consistent with methods described in U.S. EPA's "*Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*" (1985 Guidelines) (Stephan et al. 1985).

Revisions in this update are based on data that have become available since 2001. Literature searches of laboratory aquatic toxicity tests with cadmium published between 2001 and 2014 identified 90 new studies containing acute and chronic toxicity data that are acceptable for deriving the revised cadmium criteria. The relationship of cadmium toxicity to total hardness was also revised with the newly acquired data (see **Table 6** and **Table 8**). The 2015 update incorporates data for 70 new species and 49 new genera. The dataset used to develop the updated criteria is composed of 75 freshwater genera for acute toxicity (compared to 55 genera in the 2001 criteria), 20 freshwater genera for chronic toxicity (compared to 16 genera in the 2001 criteria), and 79 estuarine/marine genera for acute toxicity (compared to 54 genera in the 2001 criteria). No new chronic toxicity data were available for estuarine/marine genera.

Studies evaluating the freshwater acute toxicity of cadmium are available for nine Federally-listed species. Eight of these species are fish and one is a freshwater mussel. The most sensitive Listed species are in the family Salmonidae, as represented by the genera *Oncorhynchus* (*O. kisutch*, *O. mykiss* and *O. tshawytscha*) and *Salvelinus* (*S. confluentus*). Acute toxicity data are also available for the Listed freshwater mussel Neosho mucket (*Lampsilis rafinesqueana*). Studies evaluating the freshwater chronic toxicity of cadmium are available for four Federally-listed species, three of which are also represented by the genera *Oncorhynchus* (*O. kisutch*, *O. mykiss* and *O. tshawytscha*) and one by the genera *Salmo* (*S. salar*). Acute estuarine/marine toxicity data are available for the Listed *Oncorhynchus kisutch*. There are no acceptable chronic toxicity data for estuarine/marine Listed species. Summaries provided in the

document describe the best available data for Federally-listed species that have been tested for sensitivity to cadmium; these data demonstrate that the 2015 cadmium criteria update is protective of these tested species.

Sufficient toxicity data were available to fulfill requirements of calculating acute and chronic freshwater and acute estuarine/marine criteria using a species sensitivity distribution, as described in the 1985 Guidelines. Data were not sufficient to calculate the chronic estuarine/marine criterion and Acute-Chronic Ratios (ACRs) were therefore used to derive this criterion. The Final Acute-Chronic Ratio (FACR) for this update was derived from seven genera ACRs (three freshwater invertebrate genera, five freshwater fish genera, and one acutely sensitive saltwater mysid genus). The freshwater ACR values used represent a range of species acute sensitivities, from very sensitive to moderately sensitive, and have taxonomically-related marine species. This differs from the 2001 update, where only two saltwater ACRs were available and used to calculate the saltwater FACR; however these two species are now re-classified as a single genus, *Americamysis*.

Acute and chronic hardness slopes were revised with data for several new species. The updated acute cadmium hardness slope incorporates data for 20 species (12 species used in the 2001 draft criteria and eight new species) (see **Table 6**). The updated chronic slope incorporates data for four species (two species used in the 2001 draft criteria and two new species) (see **Table 8**). The new chronic slope uses EC₂₀ estimates for three of the four species, instead of only Maximum Acceptable Toxicant Concentrations (MATCs) used for the 2001 chronic slope (MATCs were used only for *Daphnia magna* in the 2015 slope to retain the invertebrate species).

The 2015 freshwater and estuarine/marine Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) values for cadmium are summarized and compared to corresponding 2001 criteria values in **Table 1**. The available freshwater toxicity data for cadmium, evaluated using procedures described in the 1985 Guidelines, indicates that freshwater aquatic life should be protected if the 1-hour average CMC does not exceed:

$$\text{CMC } (\mu\text{g/L, dissolved conc.}) = e^{(1.103 \times \ln(\text{hardness}) - 4.291)} \times \text{CF} \quad (\text{Eq. 1})$$

Where CF (conversion factor) = $1.136672 - [(\ln \text{ hardness}) (0.041838)]$;

and the four-day average CCC does not exceed:

$$\text{CCC } (\mu\text{g/L, dissolved conc.}) = e^{(0.7977 \times \ln(\text{hardness}) - 3.897)} \times \text{CF} \quad (\text{Eq. 2})$$

Where the CF (conversion factor) = $1.101672 - [(\ln \text{ hardness}) (0.041838)]$

more than once every three years on average.

The 2015 freshwater acute CMC is 2.1 µg/L dissolved cadmium based on a hardness of 100 mg/L as CaCO₃. The CMC was derived to be protective of the commercially and recreationally important rainbow trout (*Oncorhynchus mykiss*), consistent with procedures described in the 1985 Guidelines, and is also protective of all salmonid species for which toxicity data are available. This value is very slightly higher than the 2001 CMC of 2.0 µg/L dissolved cadmium, based on a hardness of 100 mg/L as CaCO₃. The 2015 freshwater chronic CCC is 0.73 µg/L dissolved cadmium, based on a hardness of 100 mg/L as CaCO₃, and is an increase (i.e., less stringent) from the 2001 criteria of 0.25 µg/L dissolved cadmium, based on a hardness of 100 mg/L as CaCO₃. This increase is primarily due to use of EC_{20s} over MATCs, new data for existing species and the inclusion of a new sensitive genus (*Cottus*), which now represents the third most sensitive genus.

The 2015 estuarine/marine acute CMC of 35 µg/L dissolved cadmium is more stringent than the 2001 recommended criterion of 40 µg/L, which is primarily due to the addition of three new sensitive genera, consisting of a mysid (*Neomysis*), a jellyfish (*Aurelia*) and a copepod (*Tigriopus*). The estuarine/marine chronic CCC is now 8.3 µg/L dissolved cadmium compared to the 2001 CCC of 8.8 µg/L. Available data suggest the acute toxicity of cadmium may be influenced by salinity, with a trend of decreasing sensitivity to cadmium with increasing salinity. However, this trend could not be definitively characterized and a mathematical relationship could not be described to define the dependency (see **Section 5.4.1**).

Table 1. Summary of 2001 and 2015 Draft Aquatic Life AWQC for Cadmium.

	2015 AWQC Update		2001 AWQC	
	Acute (1-hour, dissolved Cd) ^c	Chronic (4-day, dissolved Cd)	Acute (1-day, dissolved Cd)	Chronic (4-day, dissolved Cd)
Freshwater (Total Hardness = 100 mg/L as CaCO ₃) ^a	2.1 µg/L ^b	0.73 µg/L	2.0 µg/L ^b	0.25 µg/L
Estuarine/marine	35 µg/L	8.3 µg/L	40 µg/L	8.8 µg/L

^a Freshwater acute and chronic criteria are hardness-dependent and were normalized to a hardness of 100 mg/L as CaCO₃ to allow the presentation of representative criteria values.

^b Lowered to protect the commercially and recreationally important species (rainbow trout), as per the 1985 Guidelines, Stephan et al. (1985).

^c The duration of the 2015 acute criteria was changed to 1-hour to reflect the 1985 Guidelines-based recommended acute duration.

Table 7. Ranked Freshwater GMAVs.(Note: All data adjusted to a total hardness of 100 mg/L as CaCO₃ and expressed as total cadmium).

(Values in bold are new/revised data since the 2001 AWQC).

Rank ^a	GMAV (µg/L)	Species	SMAV (µg/L)
75	48,458	Midge, <i>Chironomus plumosus</i>	16,241
-	-	Midge, <i>Chironomus riparius</i>	>144,586
74	31,404	Nile tilapia, <i>Oreochromis niloticus</i>	75,693
-	-	Mozambique tilapia, <i>Oreochromis mossambica</i>	13,029
73	28,710	Common carp, <i>Cyprinus carpio</i>	28,710
72	27,070	Planarian, <i>Dendrocoelum lacteum</i>	27,070
71	24,249	Mayfly, <i>Rhithrogena hageni</i>	24,249
70	>23,794	Little green stonefly, <i>Sweltsa sp.</i>	>23,794
69	16,084	Oligochaete, <i>Rhyacodrilus montana</i>	16,084
68	15,895	Mosquitofish, <i>Gambusia affinis</i>	15,895
67	14,041	Oligochaete, <i>Stylodrilus heringianus</i>	14,041
66	13,429	Oligochaete, <i>Branchiura sowerbyi</i>	13,429
65	10,968	Channel catfish, <i>Ictalurus punctatus</i>	10,968
64	10,903	Threespine stickleback, <i>Gasterosteus aculeatus</i>	10,903
63	10,131	Oligochaete, <i>Spirosperma ferox</i>	8,935
-	-	Oligochaete, <i>Spirosperma nikolskyi</i>	11,488
62	9,701	Earthworm, <i>Varichaetadrilus pacificus</i>	9,701
61	8,169	Oligochaete, <i>Quistadrilus multisetosus</i>	8,169
60	8,028	Mayfly, <i>Hexagenia rigida</i>	8,028
59	7,867	Red shiner, <i>Cyprinella lutrensis</i>	7,867
58	7,377	Green sunfish, <i>Lepomis cyanellus</i>	5,402
-	-	Bluegill, <i>Lepomis macrochirus</i>	10,074
57	7,357	White sucker, <i>Catostomus commersonii</i>	7,357
56	6,656	Yellow perch, <i>Perca flavescens</i>	6,656

55	6,182	Flagfish, <i>Jordanella floridae</i>	6,182
54	5,100	Guppy, <i>Poecilia reticulata</i>	5,100
53	4,946	Mayfly, <i>Drunella grandis</i>	4,946
52	4,164	Tubificid worm, <i>Tubifex</i>	4,164
51	3,651	Amphipod, <i>Crangonyx pseudogracilis</i>	3,651
50	2,891	Copepod, <i>Diaptomus forbesi</i>	2,891
49	2,860	Zebrafish, <i>Danio rerio</i>	2,860
48	2,210	African clawed frog, <i>Xenopus laevis</i>	2,210
47	2,195	Crayfish, <i>Procambarus acutus</i>	898.7
-	-	Crayfish, <i>Procambarus alleni</i>	7,263
-	-	Red swamp crayfish, <i>Procambarus clarkii</i>	1,620
46	>1,917	Caddisfly, <i>Arctopsyche sp.</i>	>1,917
45	1,831	Goldfish, <i>Carassius auratus</i>	1,831
44	1,531	Fathead minnow, <i>Pimephales promelas</i>	1,531
43	1,512	Oligochaete, <i>Limnodrilus hoffmeisteri</i>	1,512
42	1,130	Northwestern salamander, <i>Ambystoma gracile</i>	1,130
41	>973.2	Snail, <i>Gyraulus sp.</i>	>973.2
40	892.1	Isopod, <i>Caecidotea bicrenata</i>	892.1
39	668.6	Lake whitefish, <i>Coregonus clupeaformis</i>	668.6
38	496.4	Cladoceran, <i>Alona affinis</i>	496.4
37	493.7	Bryozoa, <i>Plumatella emarginata</i>	493.7
36	448.2	Cyclopoid copepod, <i>Cyclops varicans</i>	448.2
35	425.3	Mayfly, <i>Baetis tricaudatus</i>	425.3
34	389.3	Pond snail, <i>Lymnaea stagnalis</i>	389.3
33	384.2	Planarian, <i>Dugesia dorotocephala</i>	384.2
32	382.6	Leech, <i>Glossiphonia complanata</i>	382.6
31	317.1	Bryozoa, <i>Pectinatella magnifica</i>	317.1
30	241.0	Worm, <i>Lumbriculus variegatus</i>	241.0

29	225.4	Snail, <i>Aplexa hypnorum</i>	225.4
28	190.8	Snail, <i>Physa acuta</i>	2,383 ^b
-	-	Pouch snail, <i>Physa gyrina</i>	190.8
27	180.2	Worm, <i>Nais elinguis</i>	180.2
26	171.0	Amphipod, <i>Gammarus pseudolimnaeus</i>	171.0
25	121.9	Hydra, <i>Hydra circumcincta</i>	207.4
-	-	Hydra <i>Hydra oligactis</i>	141.1
-	-	Green hydra, <i>Hydra viridissima</i>	41.06
-	-	Hydra, <i>Hydra vulgaris</i>	183.9
24	108.4	Cladoceran, <i>Diaphanosoma brachyurum</i>	108.4
23	103.4	Crayfish, <i>Orconectes immunis</i>	>24,972 ^b
-	-	Crayfish, <i>Orconectes juvenilis</i>	148.4
-	-	Crayfish, <i>Orconectes placidus</i>	72.11
-	-	Crayfish, <i>Orconectes virilis</i>	26,948 ^b
22	94.50	Isopod, <i>Lirceus alabamiae</i>	94.50
21	88.67	Cladoceran, <i>Moina macrocopa</i>	88.67
20	73.91	Mussel, <i>Utterbackia imbecillis</i>	73.91
19	73.80	Bonytail, <i>Gila elegans (LS)</i>	73.80
18	72.54	Cladoceran, <i>Ceriodaphnia dubia</i>	66.29
-	-	Cladoceran, <i>Ceriodaphnia reticulata</i>	79.37
17	72.07	Southern rainbow mussel, <i>Villosa vibex</i>	72.07
16	70.01	Mussel, <i>Lasmigona subviridis</i>	70.01
15	69.80	Razorback sucker, <i>Xyrauchen texanus (LS)</i>	69.80
14	69.65	Cladoceran, <i>Simocephalus serrulatus</i>	69.65
13	69.49	Mussel, <i>Actinonaias pectorosa</i>	69.49
12	67.94	Bryozoa, <i>Lophopodella carteri</i>	67.94
11	66.10	Cladoceran, <i>Daphnia ambigua</i>	27.80
-	-	Cladoceran, <i>Daphnia magna</i>	40.54

-	-	Cladoceran, <i>Daphnia pulex</i>	118.3
-	-	Cladoceran, <i>Daphnia similis</i>	143.2
10	57.18	Neosho mucket, <i>Lampsilis rafinesqueana (LS)</i>	49.46
-	-	Fatmucket, <i>Lampsilis siliquioidea</i>	39.56
-	-	Southern fatmucket, <i>Lampsilis straminea claibornensis</i>	104.4
-	-	Yellow sandshell, <i>Lampsilis teres</i>	52.34
9	42.96	Colorado squawfish, <i>Ptychocheilus lucius (LS)</i>	42.96
-	-	Northern pike minnow, <i>Ptychocheilus oregonensis</i>	5,065 ^b
8	<33.46	White sturgeon, <i>Acipenser transmontanus (LS)</i>	<33.46
7	26.29	Amphipod, <i>Hyalella azteca</i>	26.29
6	>17.05	Mountain whitefish, <i>Prosopium williamsoni</i>	>17.05
5	7.841	Cutthroat trout, <i>Oncorhynchus clarkii</i>	5.966
-	-	Coho salmon, <i>Oncorhynchus kisutch (LS)</i>	14.34
-	-	Rainbow trout, <i>Oncorhynchus mykiss (LS)</i>	4.468
-	-	Chinook salmon, <i>Oncorhynchus tshawytscha (LS)</i>	9.888
4	6.066	Brown trout, <i>Salmo trutta</i>	6.066
3	5.883	Striped bass, <i>Morone saxatilis</i>	5.883
2	4.926	Mottled sculpin, <i>Cottus bairdii</i>	4.540
-	-	Shorthead sculpin, <i>Cottus confusus</i>	5.345
1	4.750	Bull trout, <i>Salvelinus confluentus (LS)</i>	4.750
-	-	Brook trout, <i>Salvelinus fontinalis</i>	3,362^b

^a Ranked from least to most sensitive based on Genus Mean Acute Value.

^b There is a 10x difference in SMAVs for the genus, only most sensitive SMAV is used in the calculation (e.g., only bull trout was used to determine GMAV for *Salvelinus*, not brook trout).

[The following species were not included in the Ranked GMAV Table because hardness was not reported and therefore toxicity values could not be normalized to the standard total hardness of 100 mg/L as CaCO₃: Leech, *Nepheleopsis obscura*; Crayfish, *Orconectes limosus*; Prawn, *Macrobrachium rosenbergii*; Stonefly, *Pteronarcella badia*; Midge, *Culicoides furens*; Grass carp, *Ctenopharyngodon idellus*.]

LS = Federally-listed species

